PRODUCTION OF ALCOHOL FROM WHISKEY SLOP

BY
SIDNEY KAHN
J. C. HOEHN

ARMOUR INSTITUTE OF TECHNOLOGY

1912

663
K12

Rensselaer Polytechnic Institute
Hartford Graduate Center
UNIVERSITY LIBRARIES

AT 258
Kahn, Sidney.
Production of alcohol from
whiskey slop

FOR USE IN LIBRARY ONLY

ILLINOIS INSTITUTE OF TECHNOLOGY
PAUL V. GALVIN LIBRARY
35 WEST 33RD STREET
CHICAGO, IL 60616

A THESIS

PRESENTED BY

SIDNEY KAHN AND JOHN C. HOEHN

TO THE

PRESIDENT AND FACULTY

OF THE

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

BACHELOR OF SCIENCE IN CHEMICAL ENGINEERING

HAVING COMPLETED THE PRESCRIBED COURSE

IN CHEMICAL ENGINEERING.

MAY 29, 1912.

APPROVED BY

Harry McCormack

PROFESSOR OF CHEMICAL ENGINEERING

DEAN OF ENGINEERING STUDIES.

DEAN OF CULTURAL STUDIES.

-TITLE OF THESIS-

THE PRODUCTION OF ALCOHOL FROM WHISKEY SLOP.

28171

-TABLE OF CONTENTS-

(1) INTRODUCTION AND OBJECT OF THESIS.

(2) TREATMENT OF ORIGINAL SLOP.

- (a) Filtration
- (b) Evaporation

(3) TREATMENT OF CONCENTRATED SLOP.

- (a) Digestion of the material
- (b) Neutralization and Filtration
- (c) Fermentation of the extracted sugars

(4) DESCRIPTION OF THE YEAST.

(5) DISTILLATION OF THE ALCOHOL.

- (a) Apparatus
- (b) Method of determination

(6) CHEMICAL ANALYSES.

- (a) Methods

(7) CONCLUSION.

- (a) Data and results.
- (b) Curves
- (c) Discussion
- (d) Calculations of cost.

LIST OF PLATES.

PLATES.	NAME.	PAGE.
No.1.	Digestion Apparatus.	7a.
No.2	Distillation Apparatus.	19a.
No.3	Results of Run #1.	25a.
No.4	Curves of Run #1.	25b.
No.5	Results of Run #2.	26a.
No.6	Curves of Run #2.	26b
No.7	Results of Run #3.	26c.
No.8	Curves of Run #3	26d.
No.9.	Results of Run #4	27a.
No.10.	Curves of Run #4.	27b.

INTRODUCTION AND OBJECT OF THESIS.

It is a well known fact that pure ethyl alcohol has been made on a commercial scale from sawdust and wood waste of all sorts. Wooden slabs,branches of trees,misfit lumber,sawdust and other refuse wood has been treated by certain processes,and from this material a high grade of ethyl alcohol is obtained. It is claimed that this alcohol is identical in every respect to the best grain alcohol made,and can be used for every purpose that grain alcohol is used.

Our object is to apply this process to the material known as"whiskey slops"to see if alcohol can be made from it in quantities large enough to make it a commercial success. There is no doubt that alcohol can be obtained from the slops,but whether in large enough quantities will be shown in the thesis.

It is claimed that the substance in the wood which is converted into fermenable saccharoses and ultimately into alcohol is the cellulose,and in our work we will attempt to show that it is not the cellulose that is converted.

In the process of manufacturing whiskey a mixture of various grains(rye,oats,corn,barley &c)are mixed

with malt and water in the most suitable proportions, and digested for a definite time. Yeast is then added and the"mash"as it is termed,is fermented for a certain length of time under the conditions which form the maximum yield of alcohol. The product of fermentation is chiefly alcohol with small amounts of fusel oil, ethers,acetic acid &c. The alcohol and ethers are distilled at the end of the fermentation and the residual mash is run into tubs and used as a cattle food. This material is termed"whiskey slops" The actual monetary value of this slop as a cattle food is small,and it is our purpose to see if the value of the alcohol obtained by our process will make the slop a more valuable byproduct.

TREATMENT OF THE ORIGINAL SLOP.

The original slop as obtained from the distillery was contained in a fifty gallon spirit barrel. Great care was taken prior to shipment to keep the material free from contamination,and to prevent access of any injurious yeasts or moulds from the air which might cause undesirable fermentation or decomposition. The sample received was tapped from the distilling apparatus as soon as the alcohol and other volatile products of fermentation had been distilled,and was of course sterile. In order to preserve the slop,and as a further precaution to kill any yeats or moulds which might have gotten into it in the brief time of filling the barrel,an amount of formaldehyde equal to one per cent by weight of the slop was added. The barrel was then closed and sealed.

The slop as received contained about three per cent of solids and in that condition could not be handled or treated to the best advantage. Accordingly an attempt was made to filter-press the material,and in this way separate the solid matter from the liquid and then evaporate the liquor to recover all of the

dissolved solids. The filter press used for this work was the large press in the laboratory and was run under air pressures varying from 20 pounds to 120 pounds. The advantage of this treatment is of course obvious. The original material weighing about 350 pounds could be reduced to a form weighing about fifteen pounds,and as such could be handled in a much simpler and more accurate manner. The material would not lose any of it original value as far as the experiment is concerned for it is the solids in the slop and not the liquor which undergoes the important change. However,difficulties preventing proper filtration were encountered. The slop contains a small amount of albumenoids and other glutinous material,which of their own inherent nature prevent the liquor from filtering through the canvas cloths in the filter press. These difficulties could not be overcome. An attempt was made to obviate this by adding a small amount of alum(1 lb)to the liquor in order to coagulate the albumens and in this way remove the cause preventing the liquid from being filtered. But this treatment did not do any good for the liquid still could not be forced through the canvas cloths. The albumenoids are soluble in potassium hydroxide and the liquor could have been filtered by a

small addition of this,but it was thought best not to treat the slop with shemicals.

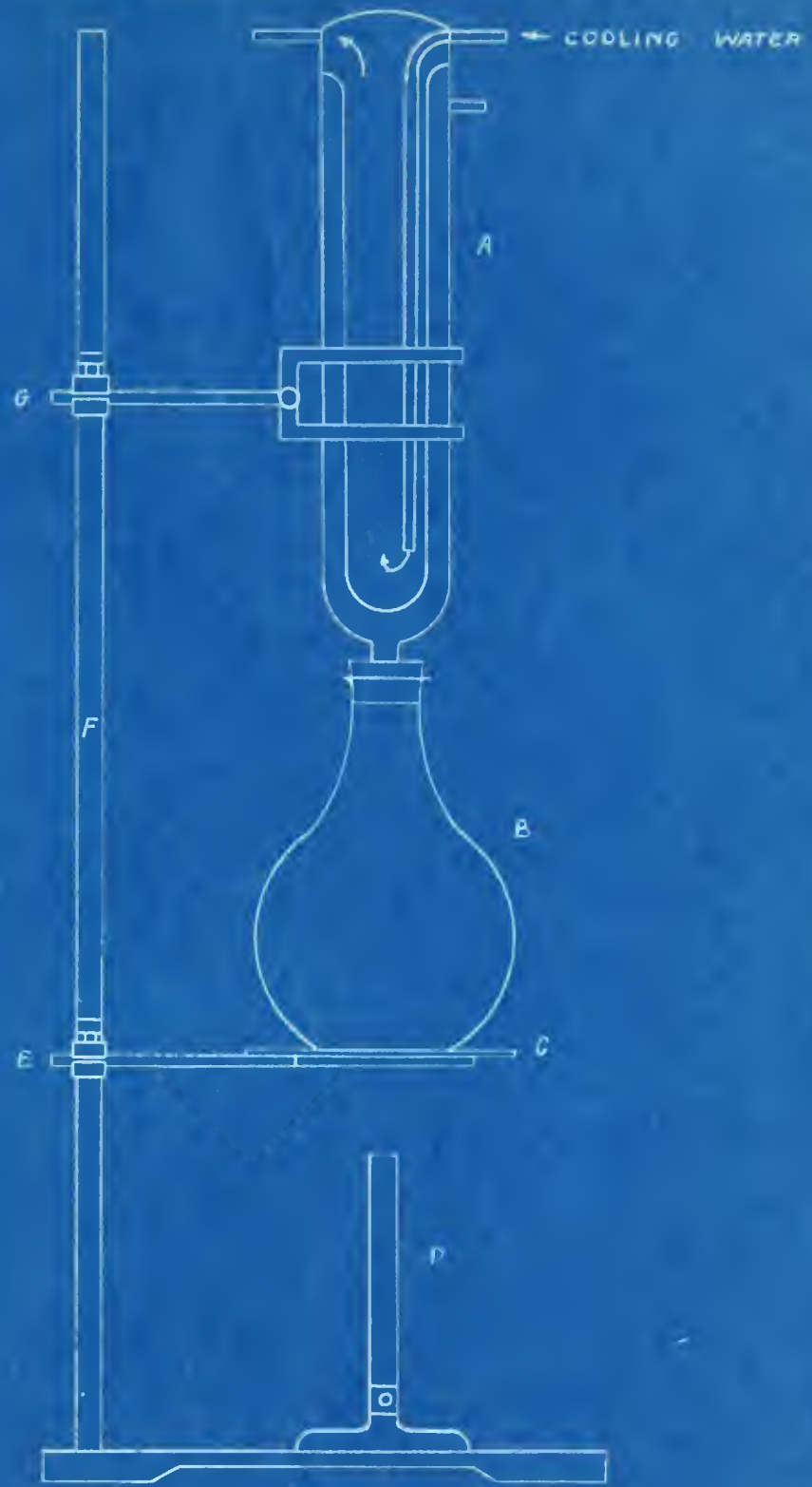
It was noticed during the attempt to filter the slop that a faint aromatic odor arose from the barrel. This odor was similar to that given by ethers which give the characteristic aroma to whiskey. An attempt was made to distill this substance from the slop,and catch it in a vessel,but the amount was so small that it was lost during the distillation. This odor could not have arisen from the barrel for it was a new one, and no whiskey had been put in it before. The possibilities of this odor being used to good advantage are excellent,for if it could have been distilled without losing any of its aroma it could be used in the manufacture of blended whiskies.

When it became apparent that the slop could not be concentrated by filtration another method,that of evaporation,was adopted. This process was carried out in two large steam heated copper kettles,each having a capacity of about twenty gallons. A small amount of acetic acid formed by fermentation was detected by its odor,and as this would attack the copper kettles during the boiling process it was neutralized with lime.

A sample of slop was analysed for total acidity by titration with a standard sodium hydroxide solution, and from this analysis the exact amount of lime necessary to neutralize the acid was calculated. The lime was added and the material well stirred. When the solids had settled the clear supernatent liquid was decanted and weighed,and then placed in the copper kettles. Steam was then admitted to the kettles and as the slop evaporated more was added from the barrel. Care was taken during the evaporation to keep the liquor well stirred in order to prevent the boiling liquid from frothing over the sides of the kettle. After all the slop had been added,the evaporation was continued until the first signs of charring on the edges was noticed. The steam was then turned off and the kettles allowed to cool over night. The concentrated slop was then removed from the kettles through a tap in the bottom, and weighed to determine the amount of water evaporated. In order to determine the actual cost of evaporation the condensed steam from the steam jackets was collected and weighed. This item will be discussed in the following chapter. The concentrated slop now has a thin pasty consistency and contained 12.4 per cent solids by analysis.

In this condition the concentrated material was susceptible to infection from wild yeasts and moulds from the air. In order to preserve it, one half liter of formaldehyde was added. The slop now weighed a little less than one third the weight of the original material, and was ready to be treated for conversion into fermentable saccharoses and the subsequent production of alcohol.

Plate #1.



DIGESTER

TREATMENT OF THE CONCENTRATED SLOP.

DIGESTION OF THE MATERIAL.

Before any work could be done with the concentrated slop it was necessary to know the amount of solids it contained, for all of our calculations and results are based on this. Accordingly an analysis was made which showed a contents of 12.4 per cent solids.

The treatment of the concentrated material was conducted in three main steps. The first was the digestion of the material with sulphurous acid to form fermentable saccharoses. The second was the neutralization of the acid and the filtration of the saccharoses formed. The third and last step was the fermentation of the saccharoses with the subsequent formation of ethyl alcohol.

The digestion of the material was conducted under various conditions in order to determine which set of conditions give the best results. Different additions of acid, variation of the time of digestion, the addition of an oxidizing agent, and other changes in the treat-

ment were tried. The results obtained from each set are tabulated in a following chapter. A complete list of the apparatus used to digest the material is given below and is shown assembled in plate #1.

LIST OF APPARATUS.

(A) Reflux Condensor

(B) Two Liter Flask

(C) Wire Gause.

(D) Bunsen Burner

(E) Iron Ring

(F) Iron Stand

(G) Universal Clamp.

The material in the barrel was stirred in order to insure a representative sample being secured. This was weighed into a two liter flask and a definite amount of sulphurous acid was diluted to a certain volume and added. Five samples were weighed in this way and each numbered. Varying amounts of acid were added to each flask which were then connected to the reflux condensors as shown. during the digestion process the five condensors were placed in series of each other,the cooling water from the first entering the second and continuing this way through-

out the series. By connecting the apparatus in this way, a more convenient and simpler method of cooling was obtained. No difficulty was encountered by the cooling water becoming warm for it was run at such a rate that the rise in temperature from the first to the last condensor was only two degrees. The object of using the reflux condensor is obvious. During the boiling of the liquid all of the vaporized water and acid are condensed and fall back into the flask,and consequently it can be boiled indefinitely without the addition of more water or acid. The slop was boiled for four hours in this manner,and at the end of this time the condensors were removed. The flasks were then boiled for another half hour to drive off as much of the acid as possible. The action of thesulphurous acid is to convert the "intercellular matter"into saccharoses and is simply a catalytic agent. None of the acid is used up during the digestion,but it must be removed or neutralized before further treatment is possible. At the end of this boiling the material is ready for neutralization and filtration.

After the first set had been digested another series of samples was weighed out and treated with acid in the

same manner as the first set. The same amount of acid was added to each flask. Each flask in this set was boiled a definite time,which was recorded,and at the end of that time was disconnected from the condensors in order to boil off as much of the acid as possible. The object of this set was to see if the same results could be obtained with shorter boiling. These results showed plainly that those digested the longer period of time were converted to the greater extent.

The next variation in the conditions under which the material was digested was the addition of a small amount of bleaching powder as an oxidizing agent before the boiling process was started. The object of this oxidizing agent was to change a portion of the sulphurous acid to sulphuric. Sulphurous acid has a greater power of converting the inter-cellular matter into saccharoses than has the sulphuric acid,but the latter has a greater tendency to dissolve the convertable matter and thus make it more susceptible to the action of the sulphurous acid. The digestion of these samples was the same as that of the preceding ones,and at the end of the digestion the condensors were removed to boil

off the acid. The material was now ready for neutralization and filtration.

Another method of treating the concentrated slop was tried. Concentrated sulphuric acid in varying amounts was added to weighed samples and these were boiled for a definite length of time. During the boiling it was noticed that the color of the material changed from a dark to a light brown and that the size of the particles of solid matter in the slop seemed to grow smaller. At the end of the digestion the flasks were neutralized and the material filtered as explained in the next chapter.

NEUTRALIZATION OF THE DIGESTED SLOP
AND
FILTRATION OF THE SACCHAROSES.

The second main step in the treatment of the concentrated slop was the neutralization of the acid left in the charge and the filtration from the non-convertible residue of the saccharoses formed. This was accomplished in two separate stages.

The first stage,that of neutralization of the excess acid,was the addition of finely pulverized chalk. This chalk was prepared by grinding ordinary commercial chalk in a large mortar. Small amounts were added at a time and the contents of the flask well shaken to obrain a thorough mixture of the chalk and the liquor. This was done while the flask was still hot in order to make the neutralization proceed as fast as possible.

Great care was taken to add small amounts at a time so that the resulting froth due to the liberation of carbon dioxide would not rise out of the flask. An excess of chalk was added to each flask which was then allowed to stand over night to insure complete neutralization.

The second stage was that of extracting the fermentable sugars from the material. These fermentable sugars are all soluble in water and can best be extracted by filtration. This filtration serves two important purposes. In the first place the sugars are separated from the solids and a clear though deeply colored solution is obtained. The process of fermentation works best in a solution free from solids,for there is no foreign waterial present which would interfer with the action of the yeast. In the second place the alcohol formed can be distilled with greater safety. The absence of solids minimizes the danger of the distilling flasks becoming locally over heated and consequently reduces the danger of cracking.

The filtration was done by means of five porcelain Buchner funnels fitting into large filter flasks. In order to increase the rate of filtration the flasks were connected to a vacuum system. Filter papers made especially for this type of a funnel were used to retain the solids. Some difficulty was encountered during the filtration due to the presence of glutinous materials referred to previously. When the neutralized material was first put into the funnel the liquor came through in a fast stream but this rate soon diminished as more

material was added. However,this did not present any serious objection for the liquor came through fast enough to warrant the use of this method. After all of the material had been put into the funnel it was washed twice with water to remove the last traces of soluble material. When this was completed the filtrates was made up to a definite volume and an aliquot portion was taken to determine the amount of sugars present. This analysis will be described later. The remaining liquor was then ready for fermentation.

FERMENTATION OF THE EXTRACTED SUGARS.

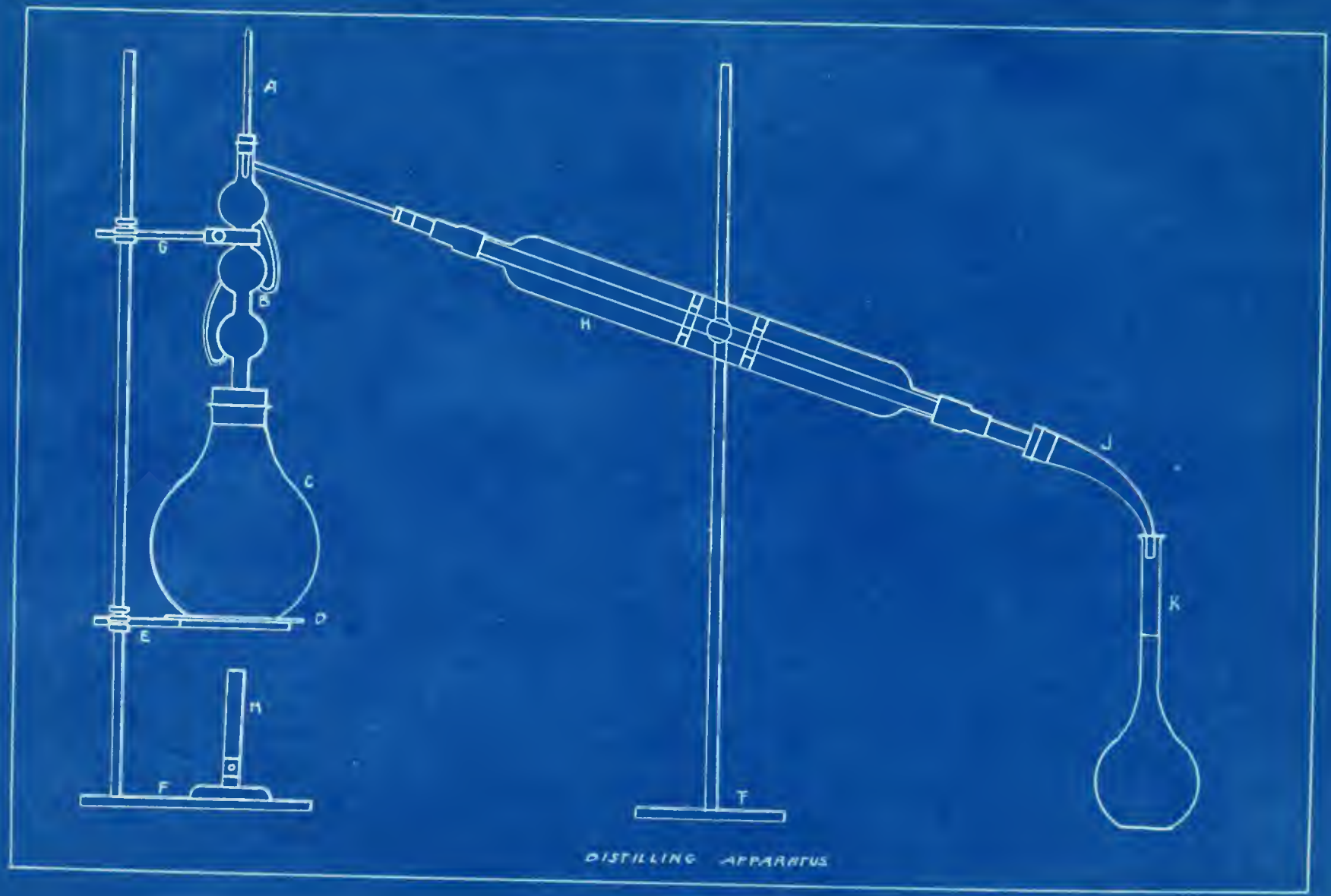
The third and last step in the treatment of the slop was the fermentation of the extracted sugars. The conditions under which the fermentation was conducted were made as near those which give the best results as possible. For the fermentation Fleischmann's compressed yeast was used. This yeast is described in the following chapter. The sugar solutions were put into one liter flasks and one fourth of a cake of compressed yeast was cut up into small pieces and added. The flasks were well agitated to obtain a thorough mixture of the yeast and the liquid, after which the necks of the flasks were plugged with cotton to exclude any wild yeast and moulds from the air. The liquor does not have to be sterile when the yeast is added for this large amount of yeast soon gains control of the solution and excludes all other kinds. The temperature of fermentation varied between 20 degrees and 25 degrees C. In order to gauge the fermentation glucose controls were used. A glucose control is simply a small amount of glucose dissolved in water. This was fermented under the same conditions as

the other flasks,and the progress of the fermentation was judged by this one. When complete fermentation was reached in the control the other were stopped and distilled immediately. Throughout the fermentation small bubbles of carbon dioxide could be seen rising to the surface,and at the end of forty eight(48)hours a thin coating of yeast had formed on the surface of the liquor. The time of fermentation was six days.

DESCRIPTION OF THE YEAST.

The yeast used to ferment the sugar solutions was Fleischmann's compress yeast. This is a type of distillers top yeast and is known technically as "Saccharomyces cerevisiae." A very good description of the yeast can be obtained in "Micro-Organisms and Fermentation" by Alfred Jorgensen, or in "Allens Commercial Organic Analysis" Vol 1. This top yeast is a pale yellowish-white mass with a peculiar ethereal odor and bitter taste, and acts best at temperatures between 18 C. and 25 C. This yeast when first compressed has a pleasant odor and does not have any dark specks or streaks in it and should be even in texture. It should be used when fresh for it easily becomes stale and deteriorates unless kept under the best of conditions. It should be kept wrapped in tin foil in a cool place. Unless these precautions are observed strictly a mouldiness rapidly developes which greatly reduces the value of the yeast. A microscopical examination of the top yeast taken from the fermenting sugar solutions showed the presence of a large quantities of moulds. This mould greatly reduces

the amount of Alcohol formed and consequently casuses low results in the yield of alcohol. The yeast in cake form was dry and crumbly, and when added to the solutions formed a compact sediment in the bottom of the flasks.



DISTILLING APPARATUS

PLATE #2.

DISTILLATION OF THE ALCOHOL.

The distillation of the alcohol was started as soon as the fermentation came to an end. A complete list of the apparatus used is given below and is shown assembled in Plate #2.

LIST OF APPARATUS.

(A) Thermometer
(B) Fractionating column
(C) Two Liter Flask
(D) Wire Gauze
(E) Iron Ring.
(F) Iron Stand
(G) Iron Clamp
(H) Water Cooled Condensor
(J) Adapter
(K) 250 cc.Graduated Flask
(L) Buneen Burner

The fermented liquor was put into the distilling flask and heated. The fractionating column was used for the purpose of obtaining a better separation of the alcohol and water,for most of the water vapor which came off at first was condensed in it,whereas the alcohol passed into the condensor. The distillation was continued until 250 cc.of the liquor had been distilled. The distillate was then analyzed for alcohol which was determined by the specific gravity method. This is a

quick and simple method and is the most accurate one known provided the liquor contains nothing else other than alcohol and water. The specific gravity of the various distillations was taken by means of a Sprengel tube. This is simply a U shaped tube with the ends drawn down to fine capillary tubes.

The volume of the tube is first determined. This is done as follows. The tube is thoroughly cleaned,washed with alcohol and then ether,and then dried by drawing air through it for fifteen minutes. The tube is then weighed. Distilled water previously boiled is put into the tube and cooled at 20 C. The water is then drawn back to a fine mark on one of the capillary tubes,by applying a piece of filter paper to the end of the other capillary. The tube is again weighed and the difference between the two weights gives that of the water. The density of pure water at 20 C. is obtained from a table and from this the volume of the tube is calculated.

In working with the distilled alcohol the same principle is used. The specific gravity is calculated from the known weight and volume of the liquor. The distillate is made up to a definite volume and a portion is drawn into the Sprengel tube by means of a water aspirator. This tube is again cooled to 20 C.and

the liquor is drawn back to the mark in the capillary as described before. The exact temperature is obtained by means of a small water bath. Cold water is run into a large beaker and just enough warm water is added to bring the temperature exactly to 20 C. The Sprengel tube is then submerged in the water with the openings in the capillary tubes just above the surface. This is allowed to stay in the water fifteen minutes. At the end of this time the contents of the tube is at the same temperature as that of the water bath. The tube is then withdrawn,dried and weighed and the specific gravity of the liquor calculated. This specific gravity is then changed by means of a temperature factor to correspond to that at 15.5 C. and the amount of alcohol present is obtained from tables.

CHEMICAL ANALYSES.

TOTAL ACIDITY.

The total acidity of the slop was determined by titration with a standard alkali solution. One hundred cc of the slop was titrated with a tenth-normal sodium hydroxide solution using phenolphthaline as an indicator. From the amount of standard alkali used the total acidity was calculated,and from this the amount of calcium carbonate required to neutralize the acid was figured.

THE STRENGTH OF THE SULPHUROUS ACID.

Ten cc. of the acid was titrated with a standard sodium hydroxide solution,and from the number of cubic centimeters of the solution required the amount of sulphur dioxide in the sulphurous acid was calculated.

DETERMINATION OF SOLIDS IN THE CONCENTRATED SLOP.

About fifty grams of the concentrated slop was weighed out in a small tared beaker. This was heated

on the steam bath for five hours. The beaker and contents were then transferred to the steam heated oven. Here it was dried for three hours and then weighed. This was repeated until two consecutive weighings checked within one milligram. Two samples were run and the per cent solids was calculated from each sample.

DETERMINATION OF SUGARS IN THE DIGESTED LIQUOR.

PREPARATIONS OF REAGENTS.

(A) Copper Sulphate Solution

34.639 gr dissolved in water and diluted to 500 cc.

(B) Alkaline Tartrate Solution

173 gr of Rochelle Salts and 50 grams of sodium hydroxide were dissolved in water and diluted to 500 cc.

Thirty cc.of the copper solution,thirty cc.of the alkiline solution and sixty cc.of water were measured into a beaker and heated to boiling. An aliquot part of the digested liquor was added and boiled for two minutes. This was then filtered immediately through a Gooch funnel without diluting. The Gooch funnels were

prepared as follows. A thin wet pad of asbestos was put on the bottom of the crucibile. This was then thoroughly washed with water to remove all small fibres. Ten cc. of alcohol was then washed through and this was followed with ten cc of ether. The crucible was then dried in a water oven at 100 degrees for thirty minutes.

In this Gooch the percipitated cuprous oxide was collected on the asbestos pad and thoroughly washed with hot water. Ten cc of alcohol and ten cc of ether were then washed through it. The Gooch was then transferred to the water oven and dried for thirty minutes.

It was then taken out,cooled and weighed. The difference in weight is that of the cuprous oxide,which when multiplied by 0.8883 give the weight of metallic copper,and from this theweight of invert sugar is found in a set of tables.

Plate #3.

RUN NUMBER I

SAMPLE	TIME OF DIGESTION HOURS	TIME OF FERMENT'G DAYS	WT. OF SAMPLE POUNDS	WT. OF SOLIDS GRAMS	WT. OF H_2SO_3 GRAMS	PERCENT OF ACID	WT. OF SUGARS GRAMS	VOL. OF FERMENT'G SOL. C.C.	VOL. OF DISTILLATE C.C.	SP. GR. OF DIST. AT 60°F	WT. OF C_2H_5OH GRAMS	RATIO WT ALC. WT SOLIDS	RATIO OF WT. SUG. TO WT. SOL.
1	4	6	2.5	140.5	.352	.25	28.6	1000	100	.99745	1.37	.975%	20.3
2	4	6	2.5	140.5	.704	.50	40.9	1000	250	.99785	2.88	2.05%	29.1
3	4	6	2.5	140.5	1.408	1.00	45.1	1000	250	.99763	3.18	2.26%	32.0
4	4	6	2.5	140.5	2.112	1.50	41.0	1000	250	.99785	2.88	2.05%	29.2
5	4	6	2.5	140.5	2.460	1.75	39.8	1000	250	.99798	2.70	1.92%	28.3
6	4	6	2.5	140.5	2.816	2.00	38.2	1000	250	.99813	2.50	1.78%	27.2
7	4	6	2.5	140.5	5.632	4.00	35.0	1000	250	.99843	2.10	1.49%	24.9
8	4	6	2.5	140.5	8.448	6.00	34.9	1000	250	.99836	2.15	1.53%	24.8
9	4	6	2.5	140.5	11.264	8.00	34.0	1000	250	.99835	2.20	1.57%	24.2
10	4	6	2.5	140.5	14.080	10.00	34.0	1000	250	.99843	2.10	1.49%	24.2

Plate #4

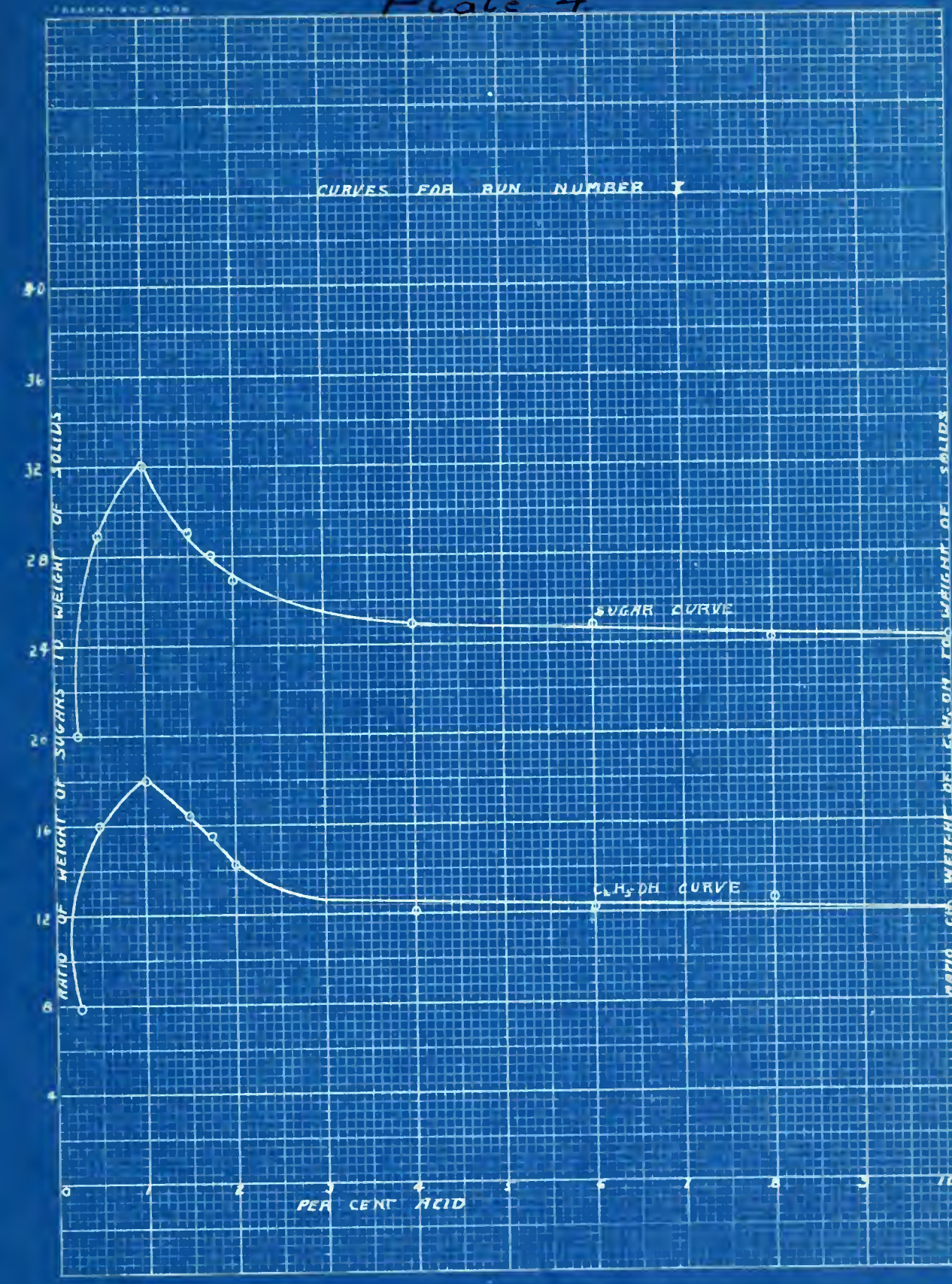

CURVES FOR RUN NUMBER I
SUGAR CURVE
C_4H_5OH CURVE
RATIO OF WEIGHT OF SUGARS TO WEIGHT OF SOLIDS
RATIO OF WEIGHT OF C_4H_5OH TO WEIGHT OF SOLIDS
PER CENT ACID
40
36
32
28
24
20
16
12
8
4
0
1
2
3
4
5
6
7
8
9
10
2.0
1.5
1.0
.5
0

Plate #5

RUN NUMBER 2.

SAMPLE	TIME OF DIGESTION HOURS	TIME OF FERMENT. DAYS	WT. OF SAMPLE POUNDS	WT. OF SOLIDS GRAMS	WT OF H_2SO_4 GRAMS	PER CENT OF ACID	WT. OF SUGARS GRAMS	VOL OF FERMENT'G SOL. CC	VOL OF DISTILLATE IN C.C.	SP. GR. OF DIST. AT 60°F.	WT OF C_2H_5OH GRAMS	RATIO OF WT. ALC. TO WT SOLIDS	RATIO OF WT. SUG. TO WT. SOLIDS
1	2	6	2.5	140.5	1.056	.75	25.1	1000	250	.99885	1.52	1.08	17.8
2	3	6	2.5	140.5	1.056	.75	40.0	1000	250	.99783	2.89	2.05	28.5
3	4	6	2.5	140.5	1.056	.75	47.2	1000	250	.99754	3.30	2.35	33.6
4	5	6	2.5	140.5	1.056	.75	46.9	1000	250	.99758	3.24	2.31	33.4
5	6	6	2.5	140.5	1.056	.75	46.7	1000	250	.99756	3.27	2.33	33.2

Plate # 6.

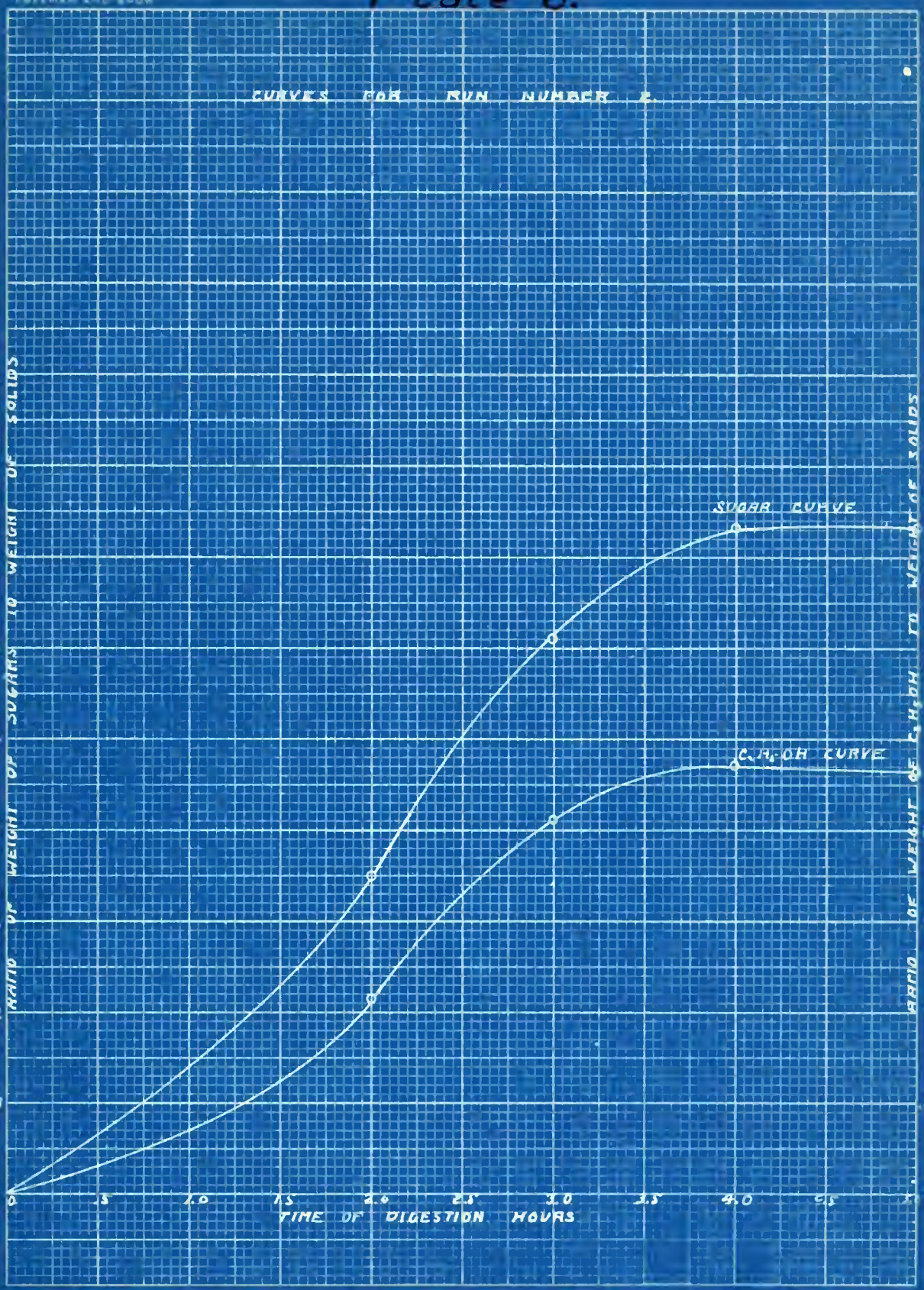
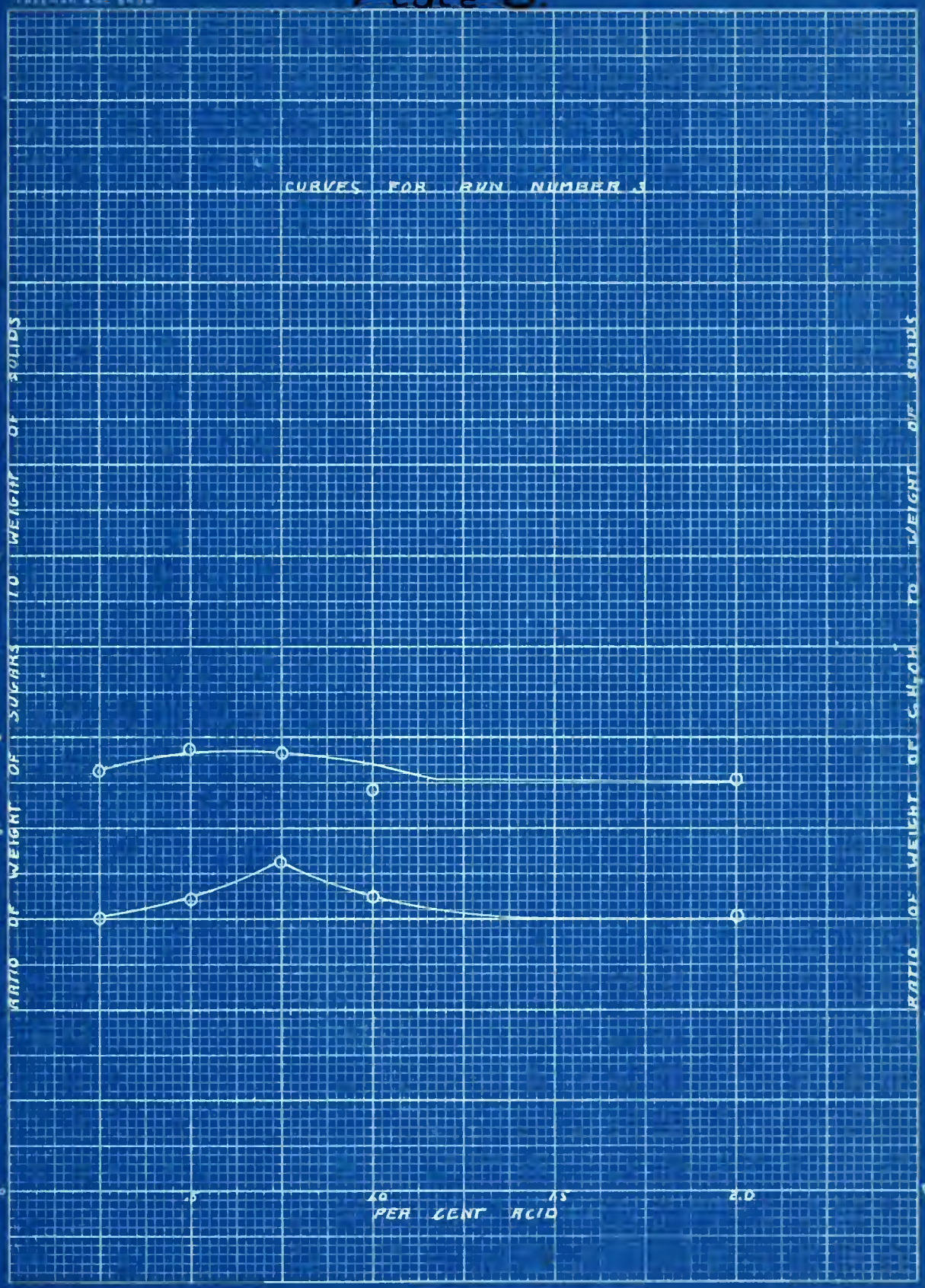

CURVES FOR RUN NUMBER 2.
SUGAR CURVE
C_2H_5OH CURVE
AMT. OF WEIGHT OF SUGARS TO WEIGHT OF SOLIDS
AMOUNT OF WEIGHT OF C_2H_5OH TO WEIGHT OF SOLIDS
TIME OF DIGESTION HOURS
40
36
32
28
24
20
16
12
8
2.0
1.5
1.0
.5
0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5

Plate #7.

RUN NUMBER 3 WITH BLEACHING POWDER

SAMPLE	TIME OF DIGESTION HOURS	TIME OF FERMENTG DAYS	WT. OF SOLIDS GRAMS	WT. OF SAMPLE POUNDS	WT. OF H_2SO_3 GRAMS	PER CENT OF ACID	WT. OF SUGARS GRAMS	VOL. OF FERMENTG SOL. C.C.	VOL. OF DISTILLATE IN C.C.	SP. GR. OF DIST. AT 60°F	WT. OF C_2H_5OH GRAMS	RATIO OF WT. ALC. TO WT. SOLIDS	RATIO OF WT SUG TO WT SOLIDS
1	4	6	140.5	2.5	.352	.25	26.1	1000	100	.99800	1.07	.762	18.6
2	4	6	140.5	2.5	.704	.50	27.0	1000	100	.99772	1.22	.868	19.2
3	4	6	140.5	2.5	1.056	.75	26.8	1000	100	.99763	1.27	.904	19.0
4	4	6	140.5	2.5	1.408	1.00	25.0	1000	100	.99780	1.18	.840	17.8
5	4	6	140.5	2.5	2.816	2.00	25.8	1000	100	.99790	1.12	.797	18.4

Plate #8.


CURVES FOR RUN NUMBER 3
RATIO OF WEIGHT OF SUGARS TO WEIGHT OF SOLIDS
RATIO OF WEIGHT OF CaOH TO WEIGHT OF SOLIDS
PER CENT ACID
40
36
32
28
24
20
16
12
8
4
0
1.0
.5
0
.5
1.0
1.5
2.0

CONCLUSION.

RUN #1.

The first set of samples digested were boiled for a definite time(four hours)with varying amounts of sulphurous acid. The object of this run was to determine at what concentration of acid the best results for this time of digestion could be obtained. Our results and curves obtained from this set are shown in plates Nos.3 and 4 respectively. In all of these samples the same amount of slop was used,so that curves could be drawn showing the relations between the amount of acid used and the yield of sugars and alcohol. These curves were drawn with per cent acid as abscissae and amounts of sugars and alcohol respectively as ordinates.

From our curves on Plate 4 it can easily be seen that the highest yield of sugars is given with a concentration of one per cent acid based on the weight of the solids. This signifies that for the best results a concentration of one per cent acid should be used for this time of digestion. The other curve shows that the maximum yield of alcohol is obtained with the same conditions.

RUN #2.

The second set of samples were run under different conditions than those of the first. This set was made with the same amount of acid(.75%)added to each flask. These flasks were then boiled for varies lengths of time in order to determine the minimum that they could be boiled in order to obtain good results. Our data and curves for this set are shown on Plates Nos.5 & 6. These curves were drawn using the time of digestion as abscissae and the amounts of sugar and alcohol respectively as ordinates. These curves have the highest ordinate at four hours and are practically horizontal after this time. This shows that the best yield of alcohol and sugar is obtained with this time of digestion.

RUN #3.

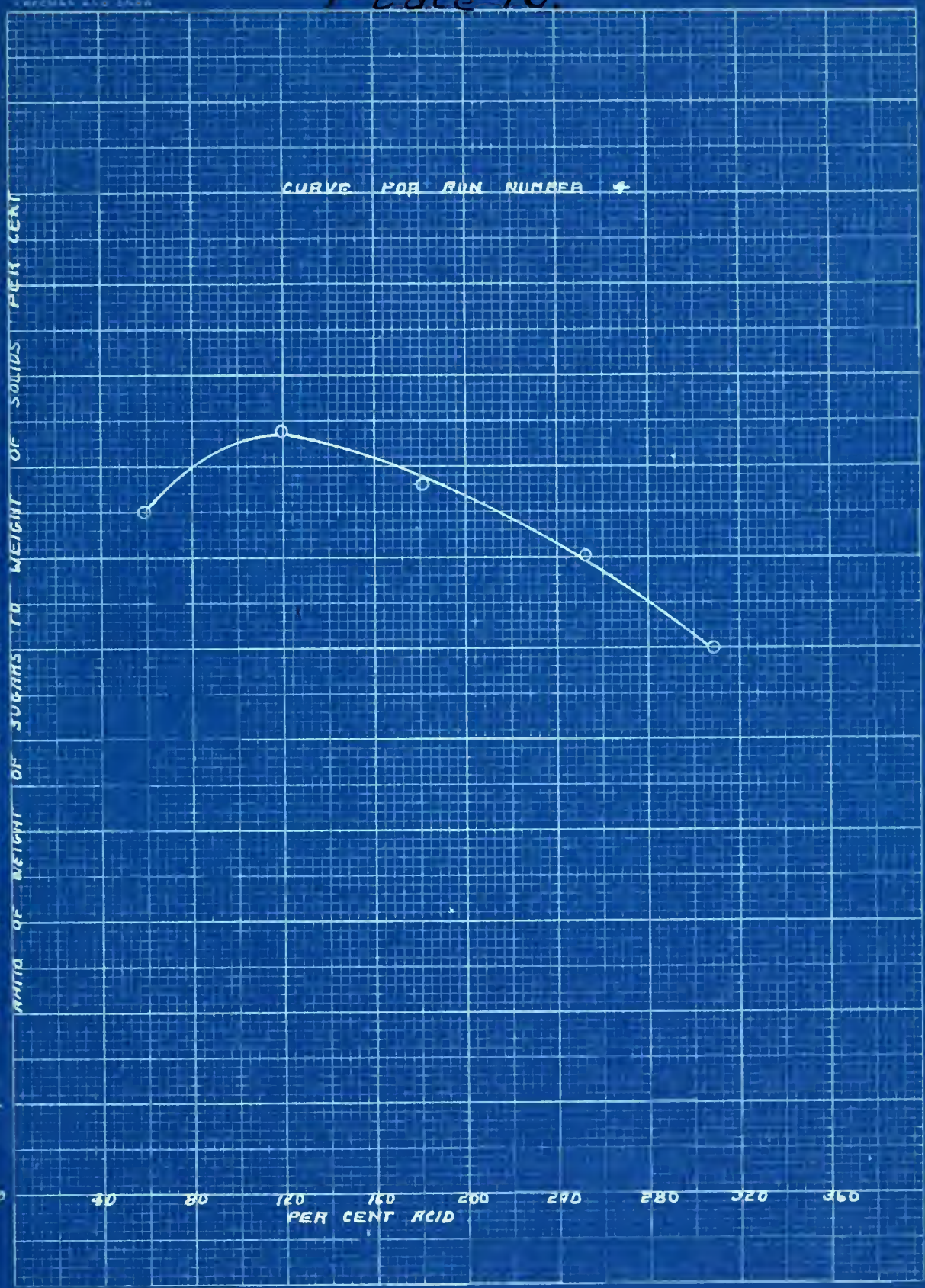
The third set of samples were run the same as the first with the addition of bleaching powder as an oxidizing agent. The object of using this bleaching powder has been explained before. Varying amounts of acid were added to each flask and the material was digested for four hours. The results and curves of this

Plate #9.

RUN NUMBER 4

SAMPLE	TIME OF DIGESTION IN HOURS	WEIGHT OF SAMPLE IN POUNDS	WEIGHT OF SOLIDS GRAMS	WEIGHT OF H_2SO_4 GRAMS	PER CENT OF ACID	WEIGHT OF SUGARS GRAMS	RATIO OF WT. SUG. TO WT OF SOLIDS %
1	3	0.50	28.15	17.5	62.2	8.63	30.6
2	3	0.50	28.15	35.0	1244	9.40	33.4
3	3	0.50	28.15	52.5	186.6	8.73	31.0
4	3	0.50	28.15	70.0	2488	7.94	28.2
5	3	0.50	28.15	87.5	311.0	7.21	25.6

Plate #10.


CURVE FOR RUN NUMBER 4
RATIO OF WEIGHT OF SUGARS TO WEIGHT OF SOLIDS PER CENT
40
36
32
28
24
20
16
12
8
4
0
40
80
120
160
200
240
280
320
360
PER CENT ACID

set are shown on Plates Nos.7 & 8. The curves are drawn with per cent acid as abscissae and amounts of sugar and alcohol respectively as ordinates.

Comparing these results with those of run #1 it is seen that the yields of sugar and alcohol in this run are far below the corresponding yields in run #1. This shows plainly that the use of an oxidizing agent during the digestion of the material is a detriment and should not be used. The maximum yield was 1.27 grams of alcohol with a concentration of .75% acid.

RUN #4.

In the fourth set sulphuric acid was used in place of sulphurous acid. The samples were digested identically the same as run #1. The results and curves of this set are shown on Plates Nos.9 & 10.using the same coordinates as before. Good results as compared with those of previous runs were obtained,but the amount of acid used for the same results was far in excess of that used in run #1. The maximum yield is obtained with an amount of sulphuric acid equal to 125% of the weight of the solids,which for the yield obtained is out of the question.

DISCUSSION.

It was stated in the introduction that alcohol could be made commercially from wood,and that in this process it was claimed by those producing the alcohol that the substance which is converted is cellulose. In our work an attempt was made to prove this is not a fact,and this is born out by our results. Cotton which is practically pure cellulose was treated in the same way in every respect that the slop was treated. After the treatment of the cotton no sugar was obtained in any case. That these sugars in the slop were formed during the digestion of the material is an absolute fact,for the slop did not contain any sugar in its original condition before treatment. As no sugars were found in the flasks containing cotton we concluded that it could not have been the cellulose in the slop which was converted.

It will be noticed that in all of the results a high amount of sugar is obtained as compared with the actual yield of alcohol. The theoretical yield of alcohol from our sugars,assuming that they are present as glucose,is five times the actual amount obtained. This small yield of alcohol is probably due to the improper yeast being used,and also that a large amount of moulds grew in the

yeast during fermentation. These moulds live on alcohol and consequently lower the amount of alcohol obtained.

CALCULATIONS OF COST.

From our results the best conditions under which the slop should be treated are the digestion for four hours with a concentration of .75% to 1.00% acid. These conditions give a yield of 3.3 grams of absolute alcohol from an original weight of 140.5 grams of solids. This yield is equivalent to 47pounds of absolute alcohol per ton of dried slop ,which is the same as 7.05 gallons of absolute alcohol or 7.40 gallons of 190 proof alcohol per ton. The value of one gallon of 190 proof alcohol to the manufacturer is 50 cents as shown below.

Market Value	$2.60
Government Tax	2.10
Value of Alcohol	.50.

At this rate one ton would produce alcohol having a total value of $3.70.

7.40 X 50 Cts $3.70.

The value of the dried slop as a cattle food is

$18.00 per ton.

As stated before the theoretical yield of alcohol is five times the actual yield, calculated from the amount of sugars present. Granting that the ideal condition could be obtained, the value of the alcohol would be $18.50 per ton.

5 X $3.70 $18.50

However the treatment of the slop, the chemicals required and the investment for apparatus would add $2.00 per ton to the cost of manufacture making a total cost of $20.00 per ton for the dried slop.

Value of slop, treatment &c per ton	$20.00
Value of alcohol recovered ,, ,,	18.50
Deficit	$1.50

These calculations show conclusively that the manufacture of alcohol from this material by our method of treatment is not a commercial success.